Coastal Sediment Transport Models and Mixed Particle Size Dynamics

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LONG-TERM GOALS

The long-term goal of our research program is to advance scientific understanding and predictive modeling of sediment-transport processes in coastal and estuarine environments. The processes are important to the Navy because they define the tactical environment in shallow water and directly affect optical and acoustic properties of the water column. The resulting seabed structure and morphology affect acoustic backscatter and ability to locate objects on or near the bottom. Predictive capabilities for coastal sedimentary processes are also of great interest to geologists, coastal resource managers, and environmental scientists interested in mitigating coastal hazards, protecting or restoring coastal resources, or remediating contaminated marine environments.

OBJECTIVES

We have been funded to participate in two ongoing ONR projects: EuroSTRATAFORM and OASIS, and we plan to collaborate on the Ripples DRI. Our long-term research goals are closely aligned with the objectives of these programs.

EuroSTRATAFORM is a coordinated research program to measure and model the oceanic and geologic processes that erode, transport, and deposit sediment on continental margins, focused particularly on those events that form and destroy beds over time scales ranging from weeks to years. The broad objective of EuroSTRATAFORM is to transfer knowledge accumulated in the ONR STRATAFORM program, incorporate the expertise and insight of European investigators, and test our developing understanding of depositional marine systems in a different environmental context. Our scientific objectives under EuroSTRATAFORM were to improve quantitative models describing the relationships among meteorological and oceanographic forcing, freshwater and sediment supply, particle dynamics, bed properties, and transport and accumulation of sediment in the coastal ocean. The objective of our modeling work has been to continue to improve the Regional Ocean Modeling System (ROMS) simulations of the Adriatic Sea, and to evaluate the model using EuroSTRATAFORM field data.

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OASIS (Optics acoustics and stress in situ) is a project funded by ONR to evaluate our understanding of suspended particle dynamics and its role in determining optical and acoustical characteristics of the water column. Field measurements will be used to evaluate a state-of-the-art model of particle dynamics and will lead to model improvements and enhanced ability to predict and interpret the optical and acoustical signature of sediments suspended by bottom stresses. The USGS participated in an OASIS experiment performed in September 2005, with the objectives of providing supporting field measurements and testing the sediment microscope camera system ("poking eyeball").

APPROACH

Our approach is to combine field observations with numerical modeling to a) improve model performance and b) use the models to interpolate and extend our insight beyond the limited field measurements. We are analyzing our data to determine velocity profiles, wave conditions, bottom stress, bottom roughness, suspended-sediment concentrations, particle characteristics, and sediment fluxes. We have built software for analysing data from newer instruments, including the Sontek pulse-coherent Acoustic doppler profiler (PCADP), the Aquatec acoustic backscatter sensor (ABS), and the Imagenex sonars. We now have programs to convert these data from their intial proprietary data formats to generic netCDF files and to perform quality checks and editing. We are also developing advanced techniques for analyzing bottom-boundary layer measurements that will provide us insight into sediment-transport mechanics. The software and processed data are distributed to the public; analyses of the data are reported in the scientific literature.

We have taken a community approach to developing our sediment-transport model, and are working with scientists and software engineers funded under the National Oceanographic Partnership Program (NOPP) to improve the Regional Ocean Modeling System (ROMS). We have used the Adriatic Sea as one of our early test-beds for improvements in ROMS, and we are now shifting our focus toward modeling resuspension and bottom features in the Ripples DRI study area.

WORK COMPLETED

EuroSTRATAFORM

USGS efforts related to the Gulf of Lions experiments are complete.

USGS scientists attended the final EuroSTRATAFORM meeting in Salamanca, Spain and presented results from the Adriatic Sea experiments.

Research intended to relate flow and sediment transport with poking-eyeball images obtained off the Chienti River during the Adriatic EuroSTRATAFORM experiment is underway. A paper outlining recent advances in sediment image acquisition and analyses has been submitted to a special issue in *Sedimentary Geology* (Rubin et al., 2006).

Significant improvements in the sediment-transport model have been made, and a paper describing USGS implementation of sediment-transport algorithms in ROMS has been submitted to a special issue of *Computers & Geosciences* (Warner et al., 2006). Also to be submitted to that special issue is a short paper describing practical methods for estimating near-bottom wave-orbital velocities from

various types of surface-wave data (Wiberg and Sherwood, 2006). Results from application of the model to the Adriatic Sea have been described in a paper by Harris et al., (2006).

OASIS: MVCO Experiment

The USGS deployed two instrumented tripods at the Martha's Vineyard Coastal Observatory as part of the OASIS experiment last autumn. The tripods were deployed approximately 10-m apart on one of the hummocky fine sand deposits that separate patches of much coarser sand. Measurements of velocity profiles, suspended-sediment profiles, suspended particle size, and bed topography were obtained. We have been collaborating with OASIS researchers to process and analyze these data. Sonar data have been partially processed and reveal intriguing large-scale features that form northeast of the tripod (Figure 1).

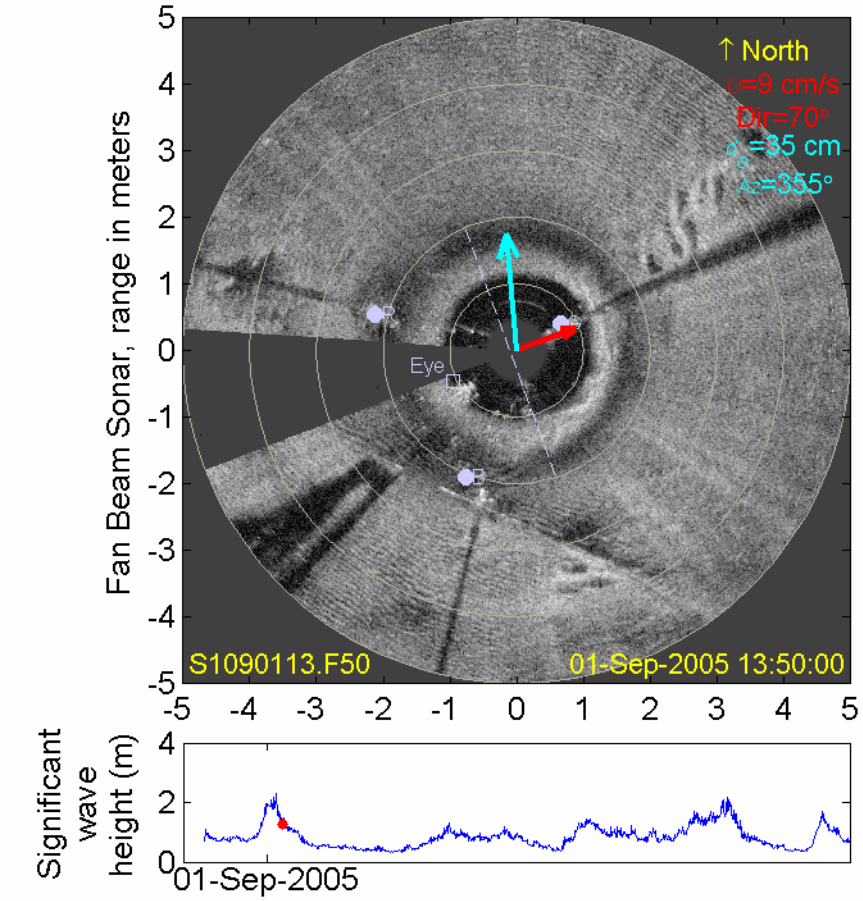

Figure 1. Image from fan-beam sonar deployed at 12-m depth on fine sand at Martha's Vineyard Coastal Observatory (top panel) and time series of wave-height from MVCO (bottom panel) showing wave conditions when this image was made (red dot). Grey circles labeled "R", "B", and "G" indicate tripod feet, and the box labeled "Eye" locates the poking-eyeball, which casts a large shadow in the SW portion of the image. Dashed line is pencil-beam sonar footprint. Although most of the bottom is covered with linear anorbital ripples (~10-cm wavelength), large (~50-cm wavelength) features have formed northeast of the tripod. Also note the unusual linear feature south of the tripod: this appears and disappears during the deployment, and may be a cable.

USGS optical data from the LISST-100 have been processed and preliminary results have been compiled by Curren et al. (2006).

The pulse-coherent acoustic-Doppler profiler data have been processed and combined with Reynolds stress measurements made by Trowbridge (WHOI). Analyses of these data are ongoing.

USGS acoustic backscatter sonar data look promising, and calibration protocols have been developed in collaboration with George Voulgaris (Univ. of S. Carolina). Final calibration runs are scheduled for October.

Additional manuscripts that have been at least partially supported by past ONR funding have been published; these include Condie and Sherwood (2006) and Sherwood et al. (2006).

RESULTS

Preliminary results indicate that a good data set with measurements of flow, suspended-sediment, and bed geometery were made during the OASIS experiment. Analyses of these data are underway, and we plan to compare them with model results.

IMPACT/APPLICATIONS

The EuroSTRATAFORM and OASIS data is being integrated with measurements of other ONR researchers. This emerging data set is being used to develop new concepts of sedimentary processes that inform our modeling efforts.

PUBLICATIONS

Condie, S. A. and Sherwood, C. R. (2006) Sediment distribution and transport across the continental shelf and slope under idealized wind forcing. *Progress In Oceanography* 70, 255-270. [published, refereed]

Curran, K. J., Hill, P. S., Milligan, T.G., Boss, E. S., Sherwood, C. R., Trowbridge, J. H , Law, B. A., Slade, W. H., and Martini, M. A. (2006) *OASIS 2005 Data Report: In situ particle size distributions*. DRAFT Data Report, Dalhousie University.

Harris, C. K., Sherwood, C. R., Signell, R. P., Bever, A., and Warner, J. C. (2006) Sediment dispersal in the northwestern Adriatic Sea. *Journal of Geophysical Research*, submitted. [refereed]

Lee, C. M., Askari, F., Book, J., Carniel, S., Cushman-Roisin, B., Dorman, C., Doyle, J., Flament, P., Harris, C. K., Jones, B. H., Kuzmic, M., Martin, P., Ogston, A., Orlic, M., Perkins, H., Poulain, P.-M., Pullen, J., Russo, A., Sherwood, C., Signell, R. P., and Thaler Detweiler, D. (2005) Northern Adriatic response to a wintertime bora wind event. *EOS Transactions of the American Geophysical Union* 86(16), 157, 163, 165. [published]

Ogston, A. S., Kineke, G. C., and Sherwood, C. R. (2006) Special volume in honor of Richard W. Sternberg's contributions to marine sedimentology. *Continental Shelf Research*, [published]

Rubin, D. M., Chezar, H., Harney, J. N., Topping, D. J., Melis, T. S., and Sherwood, C. R. (2006) Underwater microscope for measuring spatial and temporal changes in bed-sediment grain size, Sedimentary Geology, submitted. [refereed]

Sherwood, C. R., Lacy, J. R., and Voulgaris, G. (2006) Shear velocity estimates on the inner shelf off Grays Harbor, Washington, U.S.A. *Continental Shelf Research*, [published, refereed].

Warner, J. C., Sherwood, C. R., Signell, R. P., Harris, C. K., and Arango, H. G. (2006) Development of a three-dimensional, regional, coupled wave, current, and sediment-transport model. *Computers & Geosciences*, submitted. [refereed]

Wiberg, P. L. and Sherwood, C. R. (2006) Calculating wave-generated bottom orbital velocity from surface wave parameters. *Computers & Geosciences*, submitted. [refereed]

RELATED PROJECTS

NOPP Community Sediment-Transport Modeling Project – USGS participation in EuroSTRATAFORM is closely linked with the community sediment-transport modeling project because the outstanding data set from Adriatic experiments in 2002-2003 provides an unparalleled opportunity to test and improve models of circulation and sediment transport. As noted in the Long-Term Goals section, the USGS and ONR have significant overlapping scientific interest in coastal ocean processes. The USGS has contributed salary and operating expenses to the PASTA and Gulf of Lions experiments and invested significant resources into the design and construction of the poking eyeball. The USGS will continue as a partner with ONR to help advance coastal ocean modeling capabilities.

Particle Size, Bed Properties, and Transport of Sediment on European Epicontinental Shelves (Award Number: N0001404IP20093) and Transport of Sediments and Strata Formation on the Adriatic Epicontinental Shelf (Award Number N0001402IP20011) – The current project continues and expands research initiated with these projects.

Instrumentation to Measure Bottom Roughness from GEOPROBE Tripods (Award Number: N0001401F0263) – The USGS received ONR funding to develop the imaging/profiling sonar system. That project was completed in FY2002 with successful dockside testing of the new instrument. The new instrument was successfully deployed during the PASTA experiment, and obtained high-quality data (Figure 1). Plans and software for the system have been provided to other ONR investigators.